21st Century POWER PARTNERSHIP

Accelerating the transformation of power systems

FELLOWSHIP PROGRAM

Supporting Next-generation Planning Modeling Practices at South Africa's Power Utility Eskom

21CPP Fellows: Dr. Sipho Mdhuli, Prudence Rambau

Fellowship Term: Aug. 29 – Sept. 9, 2016

Fellowship Home Organization: Eskom, Energy Planning and Market Development

Fellowship Host Organization: U.S. Department of Energy's National Renewable Energy Laboratory, Energy Forecasting and Modeling Group

CLEAN ENERGY MINISTERIAL

Accelerating the Transition to Clean Energy Technologies

NREL/PR-6A20-67272

BACKGROUND

South Africa, NREL and the 21st Century Power Partnership

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- The South Africa Program connects South African stakeholders with an international community of expertise.
- Activities: demand-driven technical assistance program; network building and information exchange; sharing of global best practices; collaboration on Reports by multi-country author teams
- NREL is the Operating Agent for the 21st Century Power Partnership




SOUTH AFRICA: EMBARKING ON VAST TRANSITION AWAY FROM COAL

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95%

Amount of South Africa's annual generation produced by Eskom, the State-owned Power Utility

~4000 MW

Wind and solar energy contracted through Renewable Energy Independent Power Producer Programme since 2014

21ST CENTURY PARTNERSHIP COLLABORATION WITH ESKOM

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Under the 21st Century Power Partnership South Africa Program, Eskom and NREL have been in collaboration since 2012, focused on a range of cross-cutting issues.

- **Workshops and Trainings**: Eskom has hosted several 21CPP events on next-generation power sector topics such as renewable energy integration, opportunities for rooftop solar, and power sector planning
- **Technical Audits**: NREL has conducted technical audits of Eskom's medium- and long-term modelling capabilities under 21CPP
- **Study Tours**: Eskom has participated in several 21CPP international study tours to build capacity on a range of power sector transformation issues

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- The 21CPP Fellowship program facilitates, and in some cases provides financial support for, key individuals from 21CPP member organizations interested in short term assignments at Host Organizations.
- Assignments are intended either to develop specific capabilities in a Fellow through placement in a Host Organization with scientific or practical expertise in the needed area, or to have a Fellow with specific expertise assigned to a Host Organization where the Fellow provides targeted training and knowledge sharing.
- For more information, see: http://www.21stcenturypower.org/fellowship.cfm

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Eskom Fellows with NREL Team at Energy Systems Integration Facility

(Left to Right) Sipho Mdhluli, Eskom; Aaron Bloom, NREL; Gregory Brinkman, NREL; Matthew O'Connell, NREL; Prudence Rambau, Eskom; Erol Chartan, NREL

Through 21CPP Fellowships, two members of Eskom's Energy Planning and Market Development Group spent two weeks at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) working with the Energy Forecasting and Modeling team. Fellowship activities were supported by the U.S. Department of Energy.

- The overarching focus of the Fellowship was to improve the fidelity of Eskom's PLEXOS long-term (LT) and short-term (ST) models, which are primarily used in:
  - **Long-term Generation Expansion Exercises**, such as South Africa's Integrated Resource Plan, a process led by South Africa Department of Energy to plan large-scale generation investments (conducted in PLEXOS LT)
  - **Capacity Adequacy Assessments,** such as the Medium-term System Adequacy Outlook, a biannually conducted 5-year outlook on the capacity adequacy of South Africa's power system (conducted in PLEXOS ST)
- The growing role/prospect of variable renewable energy (vRE) in South Africa poses new modelling-related challenges that Eskom is actively working to address

FELLOWSHIP FOCUS AREAS

FELLOWSHIP FOCUS AREAS (1/2)

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1. Model Run Time Reduction

   Improving the fidelity of models sometimes results in longer run times. The first focus of the Fellowship was to explore any "low hanging fruit" opportunities for reducing model run time without significantly impacting model fidelity. More generally, exploring how various model improvements impacted runtime, and contrasting them with the value they provided, was a theme throughout the Fellowship.

2. Producing Reliable and Flexible Power Systems in PLEXOS LT

   Due to their time and geography varying nature, vRE resources can be difficult to accurately portray in planning models such as PLEXOS LT. Under this Focus Area, Fellows explored how various approaches to representing the time-related dimensions of power systems impacted the reliability and flexibility of the systems that PLEXOS LT would produce, particularly as vRE plays an increasing role.

Fellowship Focus Areas (2/2)

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3. Assessing the Flexibility of Power Systems

Power system flexibility can be understood and assessed using a range of metrics and methodologies. With increasing shares of vRE on power systems, it becomes increasingly important to assess such metrics. Under this Focus Area, Fellows learned to assess relevant flexibility metrics on PLEXOS LT results in PLEXOS ST for long-term generation expansion exercises. These metrics can also be incorporated as appropriate into the MTSAO as appropriate.

4. Incorporating Explicit Transmission Representation

Representation of network transmission constraints can significantly affect the fidelity of planning and operational models. While previously not represented, Fellows incorporated existing and planned transmission into the model. This enables (1) computation of the economic dispatch and optimal power flow in ST dispatch models and (2) consideration of transmission costs and constraints when optimizing generation resource expansion in PLEXOS LT.

OUTCOMES

1. Model Run Time Reduction
2. Producing Reliable and Flexible Power Systems in PLEXOS LT
3. Assessing the Flexibility of Power Systems
4. Incorporating Explicit Transmission Representation into PLEXOS ST and PLEXOS LT

1. Model Run Time Reduction

- The Fellows were experiencing model run times in excess of three (3) days when employing certain high fidelity methods; such run times were serving as a significant impediment to model development and analysis tasks

- The NREL Team made several proposals to reduce run time without substantively compromising the fidelity of modelled results; these were systematically explored and characterized by the Fellows using NREL's computational hardware.

- A model run time reduction of ~30% was achieved; additional potential strategies will be explored by Eskom Fellows in the near future, including strategies to better utilize Eskom's existing computational hardware to achieve quicker model run times.

2. Producing Reliable and Flexible Power Systems in PLEXOS LT

- Two methodologies for representing time dimensions of the power system were systematically compared to better understand their relative value
- *Load Duration Curve (LDC) Method*
  - Lower fidelity, shorter run time
  - Mathematical simplification; no information on time variability of load and generation, ramp events, generator cycles
  - Traditional modelling practice; useful for low shares of vRE resource
- *Chronological Sampling Method*
  - Higher fidelity, longer run time
  - Samples actual hours of operation; stronger representation of time-varying vRE resources and conventional generator ramps/cycles

2. Producing Reliable and Flexible Power Systems in PLEXOS LT

- Using both the LDC and Chronological Sampling methods, a 2050 power system was produced in PLEXOS LT. These systems were then ported into PLEXOS ST and modelled on an hour-by-hour basis to gain deeper insights into their operational costs and flexibility.
- Across a variety of metrics, a more flexible and lower cost power system was created using the Chronological Sampling method. For instance, vRE curtailment was 18x higher using the LDC method compared to Chronological Sampling for the 2050 power system on a percentage basis.
- For Eskom's long-term generation expansion model, the LDC approach was not appropriately optimizing between technologies, as it does not correctly represent the substantial vRE curtailments, conventional generator ramps, and other impacts that would occur if the system operated in real life. While Chronological Sampling better represents these aspects, employing this method take 6-8x longer to produce model results.

3. Assessing the Flexibility of Power Systems

- In the context of the unique attributes of the South African power system, Fellows conducted a series of structured discussions with relevant NREL experts on identifying and assessing power system flexibility metrics.
- The following flexibility metrics were identified:
  - Ramp frequency and size for conventional generators to meet net load
  - Hours in zero/partial/full load for conventional generators, with focus on "must run" units
  - Number of conventional generator shutdowns / startups, with focus on "must run" units
  - Variable renewable energy curtailment (%)
- As needed, these flexibility metrics will be assessed and considered moving forward by Eskom in medium- and long-term modelling exercises; additional conventional plant operational cost and performance data will be added to PLEXOS ST to provide more detailed insights.

4A. Incorporating Explicit Transmission Representation into PLEXOS ST

- Fellows worked with NREL experts to incorporate both existing and planned transmission infrastructure into PLEXOS ST and LT models, testing various approaches to optimize balance between model fidelity and runtime.
- In this process, it became quickly apparent that a basic visualization tool to understand geographic aspects of power system behavior would be necessary to both develop and validate the model augmentation.
- Fellows developed a transmission infrastructure representation that includes power flow; various model functionalities were explored to minimize runtime.
- NREL staff adapted an existing spatial visualization tool (next slide) to the Eskom model to better understand results and assess line loadings, power flow direction, zonal power flow, and other relevant aspects.

4A. Incorporating Explicit Transmission Representation into PLEXOS ST

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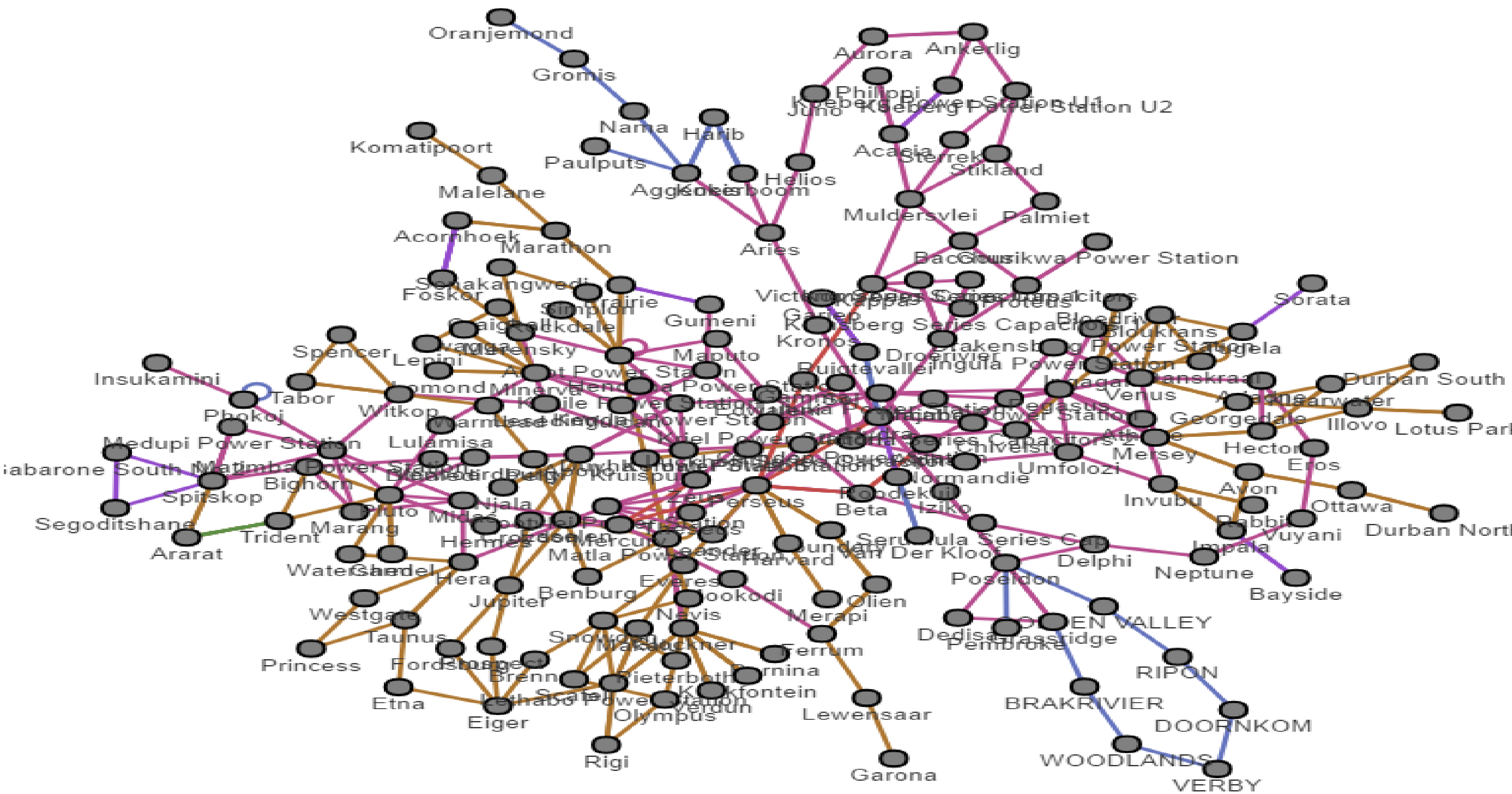

Basic Visualization Tool: Full Nodal Representation

4A. INCORPORATING EXPLICIT TRANSMISSION REPRESENTATION INTO PLEXOS ST

- To further improve model runtime while evaluating effects on model fidelity, Fellows tested the Full Nodal Representation Scheme against an Aggregated Zonal Representation of transmission in PLEXOS ST. This test assessed model run time, the adequacy of the network, and a range of other results.
- With a relative runtime reduction of ~75%, Fellows assessed that the Aggregated Zonal Representation provides sufficient fidelity in results. Fellows also learned to model a single transmission zone in detail (next slide), while leaving the rest of the network aggregated to reduce run time.

4A. Incorporating Explicit Transmission Representation into PLEXOS ST

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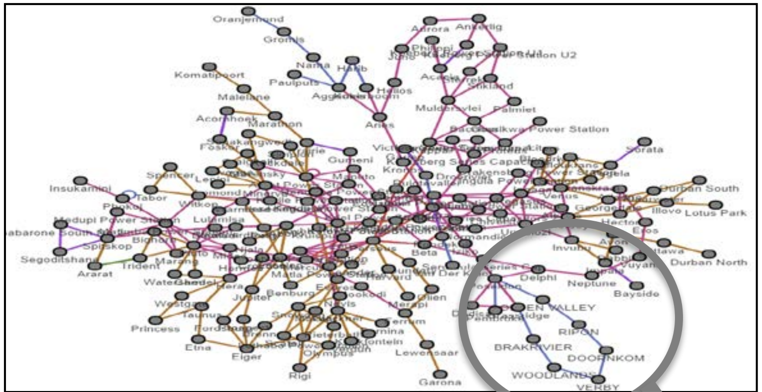
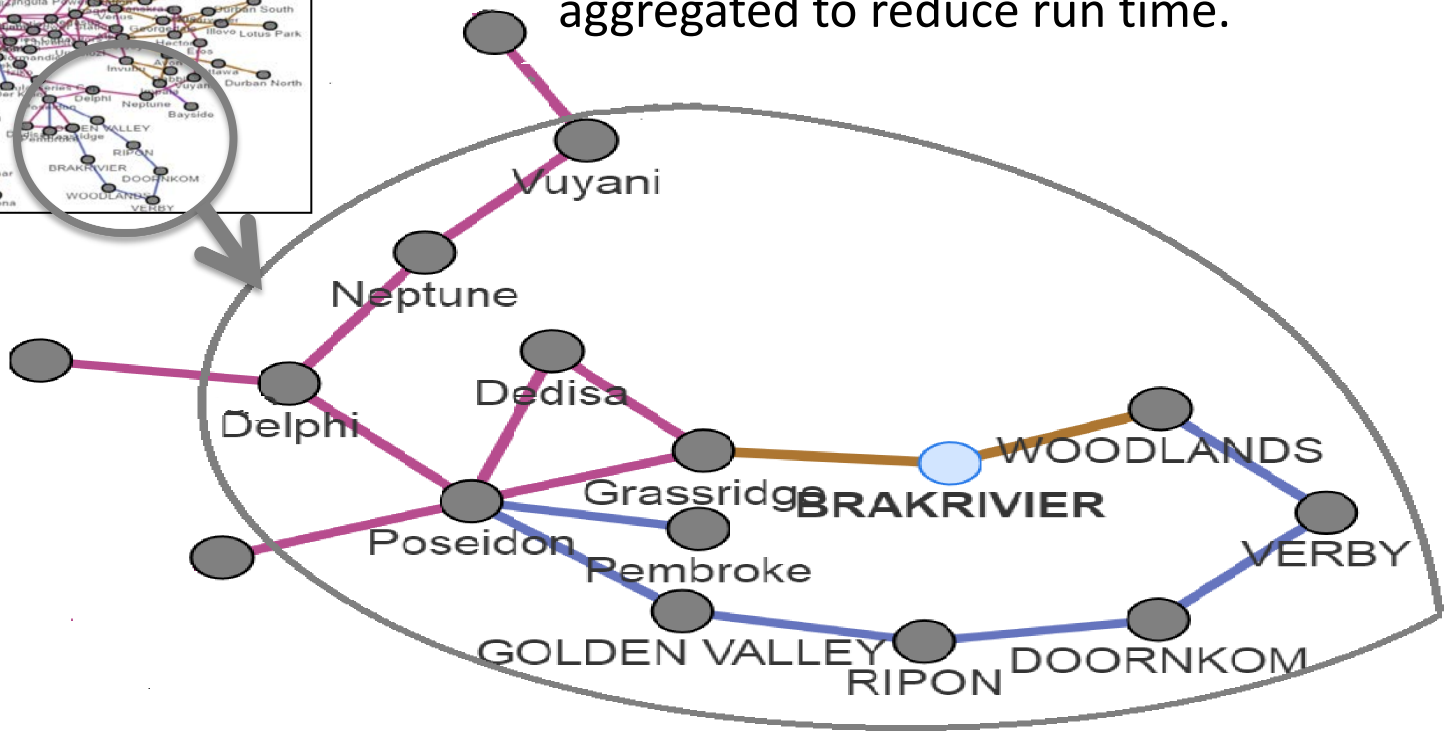


A single zone of interest can be modelled in detail while the rest of the network is aggregated to reduce run time.



Basic Visualization Tool: Nodal + Zonal Hybrid Representation

4B. Incorporating Explicit Transmission Representation into PLEXOS LT

- Upon developing an acceptable treatment in PLEXOS ST, Fellows worked with NREL staff to incorporate explicit transmission representation into PLEXOS LT. This model functionality allows analysts to better understand how generation expansion decisions are impacted by the realities of transmission grid.
- Results show that when hard transmission limits are enforced, generation expansions shift to areas with available transmission capacity, rather than simply building the lowest cost technology; this improvement will allow for the production of geographically-specific technology deployment targets which are more holistically grounded in the realities of the grid.
- This information could become useful feedback into the optimization of transmission development plans and could be incorporated into the transmission expansion planning process.

Conclusion and Follow-up

- After two weeks, the Fellows returned to Eskom equipped with a new suite of tools and skills to enhance their PLEXOS ST and LT modeling capabilities.
- However, their engagement with 21CPP and NREL is only beginning – ongoing collaboration and consultations will continue.
- Next steps and anticipated follow-up include:
    - Further exploration of spatial representation of renewables in PLEXOS LT, given transmission constraints and spatial diversity of vRE resources
    - Detailed examination of the costs and benefits of flexibility
    - Development of renewable supply curves for South Africa
    - Production of a joint Eskom-NREL technical publication

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"The 21st Century Power Partnership Fellowship program provided us with the time, space, and support to stay ahead of the curve on the next generation of power sector planning issues. We have already applied many of the lessons learned within our established modelling practices."

Prudence Rambau, Eskom

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India (co-lead) | United States (co-lead) | Denmark | Finland | Mexico | South Africa | Spain